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Nr. 7. Adolf Severin Jensen: ON FISH-OTOLITHS IN THE BOTTOM-DEPOSITS OF THE SEA. I. OTOLITHS OF THE *GADUS*-SPECIES DEPOSITED IN THE POLAR DEEP

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ON FISH-OTOLITHS

IN THE

BOTTOM-DEPOSITS OF THE SEA

I. *OTOLITHS OF THE GADUS-SPECIES DEPOSITED IN THE POLAR DEEP*

BY

ADOLF SEVERIN JENSEN

KØBENHAVN
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By the "Polar Deep" I mean the deep sea, which is situated below the 300 fathom-line and which in east is adjacent to the Spitzbergen—Norway slope, in south to the submarine ridge, connecting Europe with Greenland across the Shetland—Færoe Isles and Iceland, in west to North Greenland. This deep sea has ice-cold water (ca. 0° to —1·3° C.) everywhere at the bottom, for which reason I find the name "Polar Deep" suitable [1]).

The fish-fauna of this deep sea I have studied rather thoroughly, whenever I had the opportunity of doing so. At first my studies were limited to the material collected by the Danish Ingolf Expedition of 1895—96, by the Norwegian North-Atlantic Expedition of 1876—78 and by the Swedish arctic expeditions of 1898 and 1900, under the direction of A. G. Nathorst and G. Kolthoff. Later on I had the opportunity of studying nature itself, as Dr. Johan Hjort's kind invitation enabled me to join the investigations which were carried on from the steamer "Michael Sars" in the summer of 1902.

I hope ere long to be able to publish a detailed account of these investigations. As an introduction to the subject indicated by the heading I feel, however, obliged shortly to mention a few particulars at present.

With regard to the quantity of fish, it is greater than we perhaps would feel disposed to think judging from the low temperature which lasts in the Polar Deep all the year round. The greatest number of specimens which "Vöringen" caught in one haul was 11 (Depth: 658 fms.), but the apparatus it used were not fit for capture of fish. The "Ingolf"s improved Sigsbee trawl of a span of 10 feet already carried it as far as to catch 27 fishes in one haul (Depth: 957 fms.) and the "Michael Sars" otter-trawl with 50 feet head-line caught up to 52 fishes in one haul (Depth: 975 fms.).

Qualitatively seen, the fish-fauna of the "Polar Deep" may on the contrary be characterized as very poor. From the Shetland-Færoe Channel up to the level of Spitzbergen and from the Norway slope towards the East-Greenland the trawl will over and over again bring up the same forms to a wearisome monotony. If we count all the species, the ordinary as well as the rare, the number is not higher than 23. They divide into the following groups:

Cottoids: *Cottunculus microps*, Collett.
— *subspinosus*, Jensen.
Artediellus uncinatus, Reinhardt.
Agonus decagonus, Bloch-Schneider.

Liparids: *Liparis Fabricii*, Kröyer.
Careproctus Reinhardti, Kröyer.
— *micropus*, Günther.
Paraliparis bathybii, Collett.
Rhodichthys regina, Collett.

Lycodinae: *Lycodes frigidus*, Collett.
— *Esmarkii*, Collett.

[1]) On the charts the surface of this sea is marked by other names: The Norwegian Sea, the Greenland Sea etc.

Lycodes eudipleurostictus, JENSEN.
— *pallidus*, COLLETT.
— *platyrhinus*, JENSEN.
— *Lütkenii*, COLLETT.
— *seminudus*, REINHARDT.
Lycenchelys muraena, COLLETT.
Lycodonus flagellicauda, JENSEN.

Cod Fishes: *Onus Reinhardti*, KRÖYER.
Flat Fishes: *Hippoglossus hippoglossoides*, WALBAUM.
Sharks: *Somniosus microcephalus*, BLOCH-SCHNEIDER.
Rays: *Raja radiata*, DONOVAN.
— *hyperborea*, COLLETT.

The 13 of the named 23 species do not really have their proper home in the Polar Deep; they are for the greater part arctic fishes which in the far North live on lesser depths, partly even in shallow water; with decreasing frequency they go down to the upper region of the Polar Deep.

The indigenous species of the Polar Deep are only 10, namely: *Cottunculus subspinosus, Careproctus micropus, Paraliparis bathybii, Rhodichthys regina, Lycodes frigidus, Lycodes platyrhinus, Lycodes Lütkenii, Lycenchelys muraena, Lycodonus flagellicauda* and *Raja hyperborea*[1]). I also recognize these, however, as originally migrated from arctic coasts. In the lapse of time they have quite broken off the connection with their former home, and now they appear as particular species and genera. It is certainly not by chance that half the indigenous species belong to one single small group of Teleostei, viz. the *Lycodinae*. These specific arctic fishes possess to a rare degree the ability of forming local varieties, whose characteristic features may often assume such an extension, that the subjective view regarding the species- and variety definition will find a wide margin[2]). The other predominating group also consists of highly differentiated Teleosts[3]), namely the *Liparidae*, and the transformation of the paired fins, which takes place in these fishes — the setting up of particular genera is an expression for this — can only be understood from this point of view: successive migration and adaptation to the life in the deep sea. The Liparis-species of the coast-belt (in this case the arctic *L. liparis*, L. and *L. Fabricii*, KR.) have, as is a well-known fact, a large sucker under the belly (Fig. 1 a). This sucker has developed from the united and transformed ventral fins. The many firm objects of the bottom, as stones, sea-weed etc., are good objects for an adhesive organ, which secures these fishes from being tossed about by the current and waves. At greater depths, from about 50 fms., where the bottom becomes soft and the firm objects are scarce, the *Liparis* is replaced by the "genus" *Careproctus* whose sucker is considerably reduced in size (Fig. 1 b); the lower rays of the pectorals are at the same time elongated, projecting as threads over the connecting membrane, so that the pectorals fall as into three divisions: an upper part which resembles an ordinary pectoral fin, a middle part with short rays, and a lower part with long free rays (Fig. 2 b). A trace of such a differentiation we may however already notice in *Liparis*, as far as a notch here appears in the hind margin of the pectoral (Fig. 2 a). At still greater depths in the Polar Deep, where the bottom consists of soft mud, and where a sucker would be of no use, the genus *Paraliparis* lives. It

[1]) In my "Ichthyologiske Studier" (Vidensk. Medd. Naturhist. Foren. Kbhvn. 1901, p. 191—215) I have pointed out, that it is owing to errors, when several of these species are stated also to live in the deep of the warm Atlantic (that means the deep sea south of the named submarine ridge between Europe and Greenland). Likewise I have called the attention to the incorrectness of the reverse statement, that a species described from the deep of the Atlantic also should occur in the cold Polar Deep.

[2]) Comp. my treatise on "The North-European and Greenland Lycodinae" (The Danish Ingolf Expedition, II, 4, 1904) such examples as: *Lycodes Vahlii-lugubris-gracilis* (p. 19), *L. pallidus-similis-squamiventer* (p. 46 & p. 50) and *L. Rossii-Lütkenii* (p. 61).

[3]) That the *Lycodinae* and *Liparidae* belong to the most highly differentiated groups of the Teleostei, is also evident by the fact that they are without air-bladder.

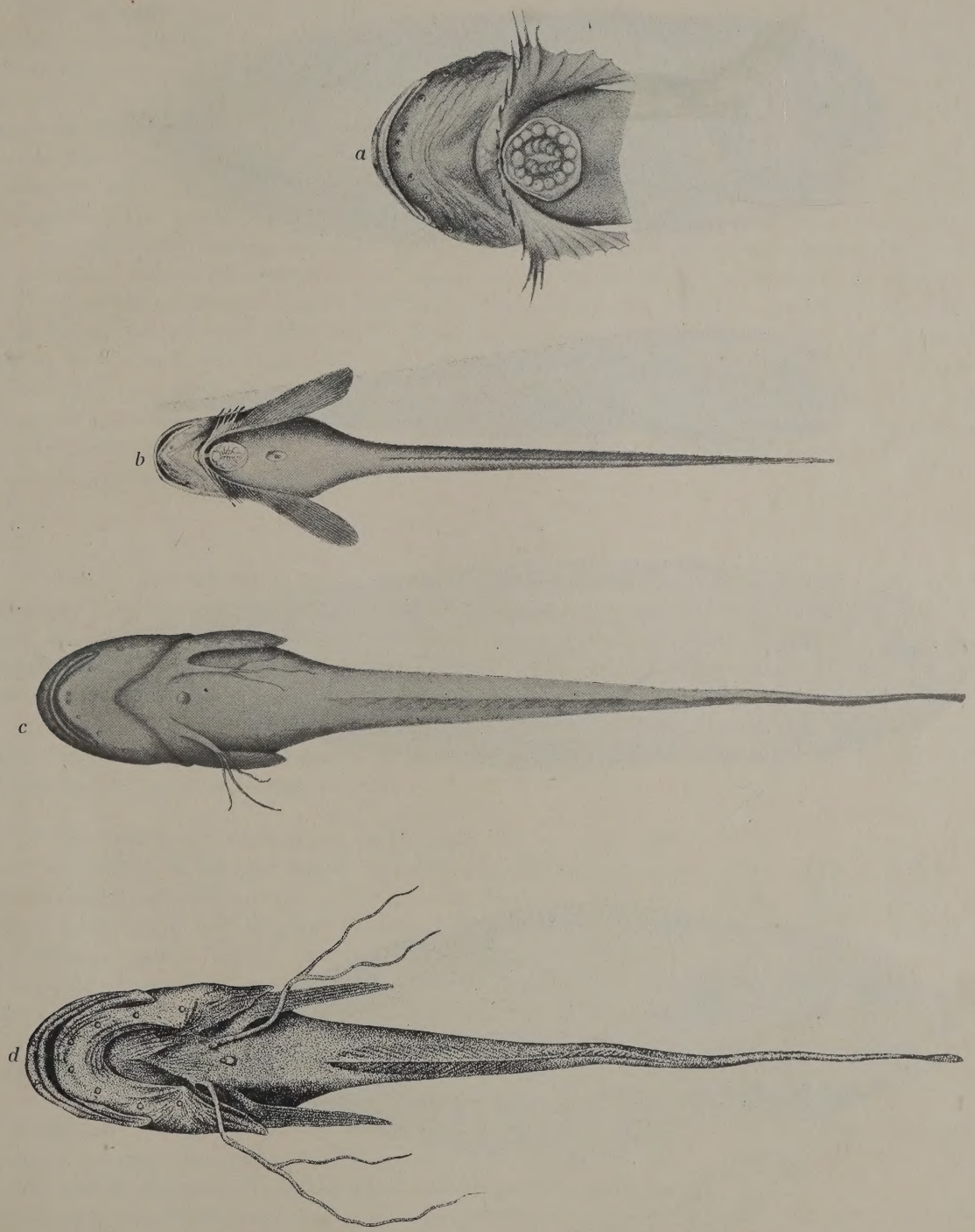

Fig. 1. *a. Liparis Fabricii*, Kr. (after Lütken). *b. Careproctus Reinhardti*, Kr. (after Collett). *c. Paraliparis bathybii*, Coll. (original). *d. Rhodichthys regina*, Coll. (after Collett). — They have all been figured from the ventral side in order to show how the sucker (which originates from a unition and transformation of the ventral fins) from being very conspicuous in the *Liparis* (*a*) of the coast-belt, becomes reduced in the sublittoral *Careproctus* (*b*), and finally quite disappears in the abyssal *Paraliparis* (*c*) and *Rhodichthys* (*d*). At the same time it may be noticed that the lower rays of the pectorals gradually assume the character of ordinary ventral fins and are substituting those. Comp. besides pp. 4, 7.

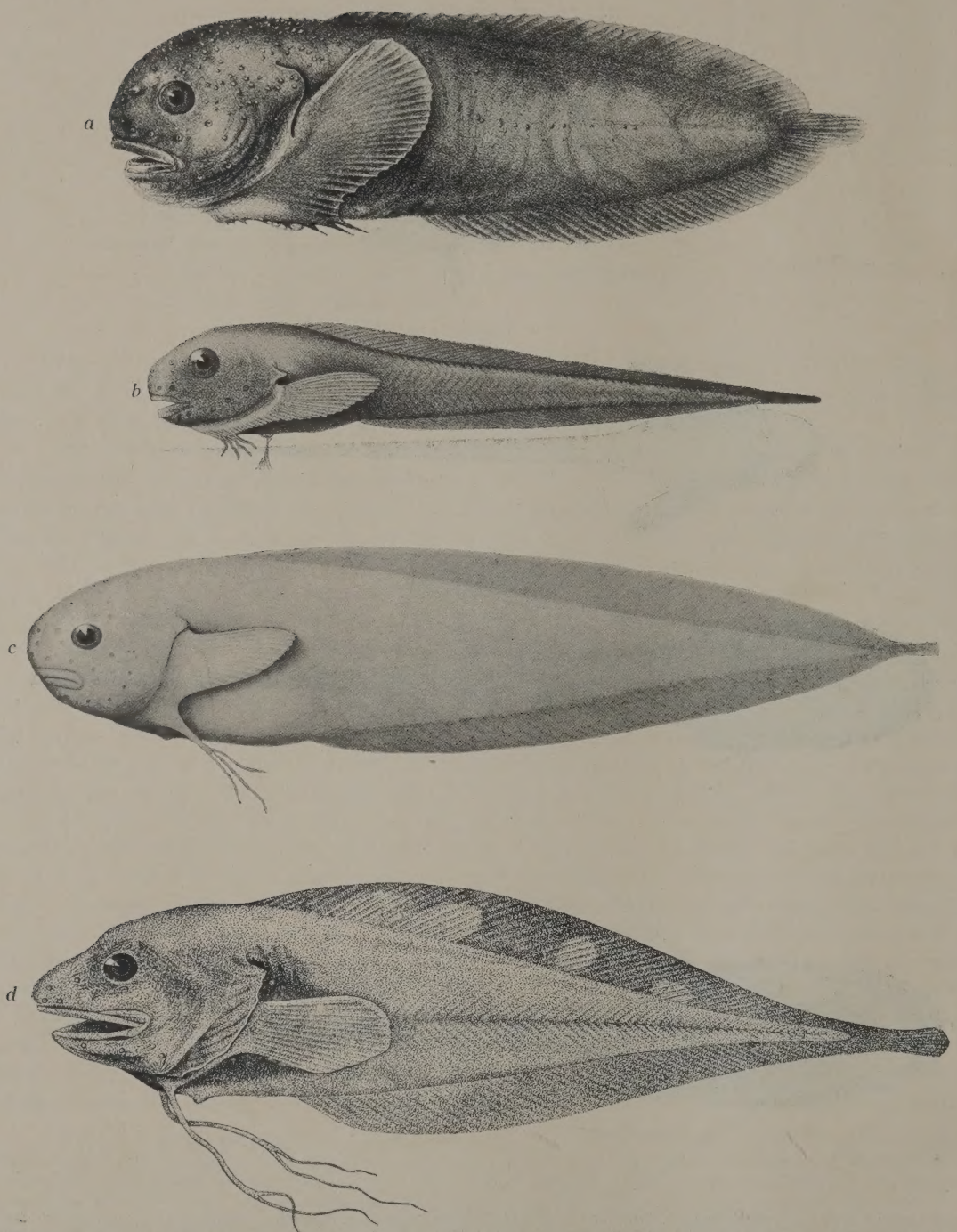

Fig. 2. The same four genera of Liparids as on the previous page. — They have all been represented from the side to show how the lower rays of the pectorals more and more separate themselves from the upper part of these fins and finally assume the character of "ventral fins". Comp. besides pp. 4, 7.

has quite lost the sucker, but to make up for the loss of ordinary ventral fins the lower rays of the pectorals have developed into a particular fin, which is separated from the upper part of the pectorals by a distinct interval (Fig. 1 c and 2 c). As ventral fins here on the soft bottom are of good use to the fish, and as an organ, so specially transformed as a sucker, is unable again to change into ordinary ventral fins, the fish has substituted the ventral fins by "borrowing" from the pectorals. At last we find as a final link of the whole series the genus *Rhodichthys* which lives far down in the Polar Deep (650—1280 fms.). It does not show any trace either of veritable ventral fins, as the sucker on the ventral region has disappeared. The Ichthyologists, nevertheless, describe *Rhodichthys* as provided with ventral fins; they have however looked too long at the few-rayed, thread-shaped highly elongated lower part of the pectorals, which in this fish is separated from the upper part of the fins by a long interval and situated quite down at the ventral margin (Fig. 1 d and 2 d). If we examine the skeleton, it will be seen that the thread-shaped "ventral fins" really develop from the lower part of the shoulder girdle and thus morphologically form a part of the pectorals. Externally they have a stricking resemblance with ventral fins — and naturally they work like those[1]). — Now we have only two species left, viz.: *Raja hyperborea* and *Cottunculus subspinosus*, and it is not difficult to point out their prototypes in the coast belt; *Raja hyperborea* is, according to my opinion, nothing but a local form of the variable *Raja radiata*, and *Cottunculus subspinosus* approaches *Cottunculus microps*.

Having now shortly given an account of the fish-fauna in the Polar Deep, its composition and origin, I shall proceed to our real subject, namely the numerous fish-otoliths which the Danish Ingolf Expedition has brought up in its trawl from the bottom of the Polar Deep. These otoliths belong to quite other fishes than those, we just have mentioned, and they might possibly be taken as an evidence that the Polar Deep is inhabited by the corresponding fish-species.

By examining the numerous bottom-samples, which the Ingolf Expedition took home, I often found otoliths. They occurred most frequently and in greatest numbers in the mud from the deep stations between the Færoes—Jan Mayen—Iceland.

The otoliths or earstones of the Teleosts are, as is a well-known fact, rather considerable bodies consisting of an organic substance with imbedded carbonate of lime. They are very hard and shine like china. Their shape and sculpture is very characteristic and varies from genus to genus. In the case in question I was even most frequently able — namely when the otoliths were well-preserved — with certainty to refer them to definite fish-species, having provided material for comparison by taking otoliths of fish, kept in the collection of the Zoological Museum of Copenhagen or from fresh specimens.

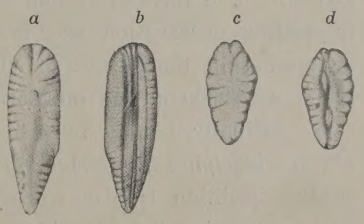

Fig. 3.
Otoliths from the Polar Deep.
a, b Otolith of *Gadus poutassou* seen from the outer side and the inner side. × 2.
c, d Otolith of *Gadus saida* also seen from the outer side and from the inner side. × 4.

The otoliths from the bottom of the Polar Deep appeared for the greater part to originate from different cod-species, and I shall now present a complete list comprising them all. The situation of the stations will be seen partly from the added central positions, partly on the accompanying chart-sketch (Fig. 4, p. 9), on which they are marked with a line under the number.

[1]) Collett has been mistaken in describing *Rhodichthys*, when he attributes ventral fins "attached to the hyoid bone" to this fish and consequently places this genus inside the family *Ophidiidae* (The Norwegian North-Atlantic Expedition. Zoology, Fishes, 1880, p. 153 f. f.) but Collett had only one single specimen of the fish at hand and was consequently unable to make it the object of a detailed examination. I hope soon in details to prove *Rhodichthys* to be a Liparid without a sucker.

Station	Latitude	Longitude	Depth	Fish-species	Number of otoliths	
117 ...	69°13′ N.	8°23′ W.	1003 fms.[1])	*Gadus callarias* L.	1	of a specimen of $^2/_3$ m.
141 ...	63°22′ -	6°58′ -	679 —	*Gadus virens* L.(?)	1	of a very small specim.
102 ...	66°23′ -	10°26′ -	750 —	*Gadus poutassou* Risso[2])	7	
103 ...	66°23′ -	8°52′ -	579 —	— — —	1	
104 ...	66°23′ -	7°25′ -	957 —	— — —	2	
105 ...	65°34′ -	7°31′ -	762 —	— — —	3	
113 ...	69°31′ -	7°06′ -	1309 —	— — —	ca. 110	of both small and large specimens
117 ...	69°13′ -	8°23′ -	1003 —	— — —	2	
118 ...	68°27′ -	8°20′ -	1060 —	— — —	3	
119 ...	67°53′ -	10°19′ -	1010 —	— — —	5	
139 ...	63°36′ -	7°30′ -	702 —	— — —	8	
141 ...	63°22′ -	6°57′ -	679 —	— — —	22	
59 ...	65°00′ -	11°16′ -	310 —	— — —	1	
102 ...	66°23′ -	10°26′ -	750 —	*Gadus saida* Lep.	4	of small and median-sized specimens
125 ...	68°08′ -	16°02′ -	729 —	— — —	6	

The attempts made in 1902 with the "Michael Sars"s powerful otter-trawl have however proved that no cod live in the Polar Deep[3]), and we must therefore see, if the deposit of otoliths on the bottom of this deep sea may be explained otherwise.

With regard to the polar-cod (*Gadus saida* Lep.) a simple explanation is just at hand. E. Bay who took part in Ryder's Expedition to East Greenland in 1891—92 narrates, that *G. saida* twice occurred in the drift-ice (75°30′ N. 7°11′ W.; 68°43′ N. 19°14′ W.[4]), and both he and the late Zoologist Søren Jensen, who took part in Lieutenant Amdrup's Expedition to East Greenland in 1900, observed frequently during the voyage in the field-ice small fishes, which they undoubtedly quite rightly took for *G. saida*. Jensen writes thus in his diary (July 2—6, 1900; ca. 72½°—74½° N. 4⅔°—6½° W.): "Often, when we came in collision with the ice-sheets, a small fish appeared which I suppose to be *Gadus saida*. It was sitting on the ice-foot in the corner between this and the ice-sheet." "During these days where we have been lying in rather compact ice many small fishes (*G. saida*) were seen." "*G. saida* is constantly seen; in the thicker ice, through which the ship advances with difficulty, it is frequently observed." The Kolthoff-Expedition to East Greenland in 1900 made similar experiences. E. Lønnberg writes as follows: "A very interesting observation was made concerning the habits of the polar-cod, which was found abundantly swimming in the surface of the sea round the drifting ice, even in such places, where the depth of the water was 2000 m. and more[5]).

Finally I may refer to the fact that during the "Fram"s drift over the polar sea a kittiwake (*Rissa tridactyla* L.) was shot, in whose stomach a polar-cod was found. Another experience from Nansen's polar expedition is also worthy of mention: "*Gadus saida.* This species was only once observed in the ice itself during the expedition. On July 16th, 1895, in 84°42′ N. Lat., Dr. Blessing, when on an excursion

[1]) 1 Danish fathom = ca. 1·89 meters.

[2]) It is possible that some of the most decayed otoliths wrongly have been referred to *Gadus poutassou*; they cannot be mistaken when well-preserved, as they easily may be distinguished from the otoliths of other Northern *Gadus*-species by their lengthened shape (Fig. 3, a & b, p. 7). The otoliths of *Gadus merlangus* may sometimes resemble them, but they are — in opposition to those of *G. poutassou* — obliquely cut off at the broad end.

[3]) It must however not be left unmentioned that by a shooting in the Polar Deep E. of the Færoe Isles (Depth: 356 fms., temp. at the bottom: — 0°51 C.) a *Gadus virens* was caught of a length of 1 m., but it may have taken the bait, when the line was hauled up through the upper layers. After a trawling in the Polar Deep E. of Iceland (Depth: 300 fms., temp. at the bottom: — 0°38 C.) a *G. callarias* of a length of 94 cm. was caught in the gear, but it may have come into the trawl during the hauling up. In its stomach were found a capelan (*Mallotus villosus*) and Schizopods.

[4]) E. Bay: Hvirveldyr. Medd. om Grønland, XIX, 1894, p. 54.

[5]) E. Lønnberg: The fishes of the Swedish zoological polar-expedition of 1900. Revue internationale de pêche et de pisciculture, II, No. 4, p. 13. St. Pétersbourg 1900.

to collect *algae*, saw a specimen of a *Gadus* lying motionless in front of a projecting piece of ice in a channel; but it disappeared under the ice like lightning, when he attempted to come near it. Its length was about 120 mm. No other fish has hitherto been observed so far north as this" [1]).

Bay feels inclined to think, that *G. saida* — at least at a young age — may live a pelagic life, and Lønnberg writes that it sometimes lives a pelagic life. Søren Jensen, on the contrary, sets forth another opinion in his diary, viz., that *G. saida* is no pelagic form, no more than the Amphipods (and

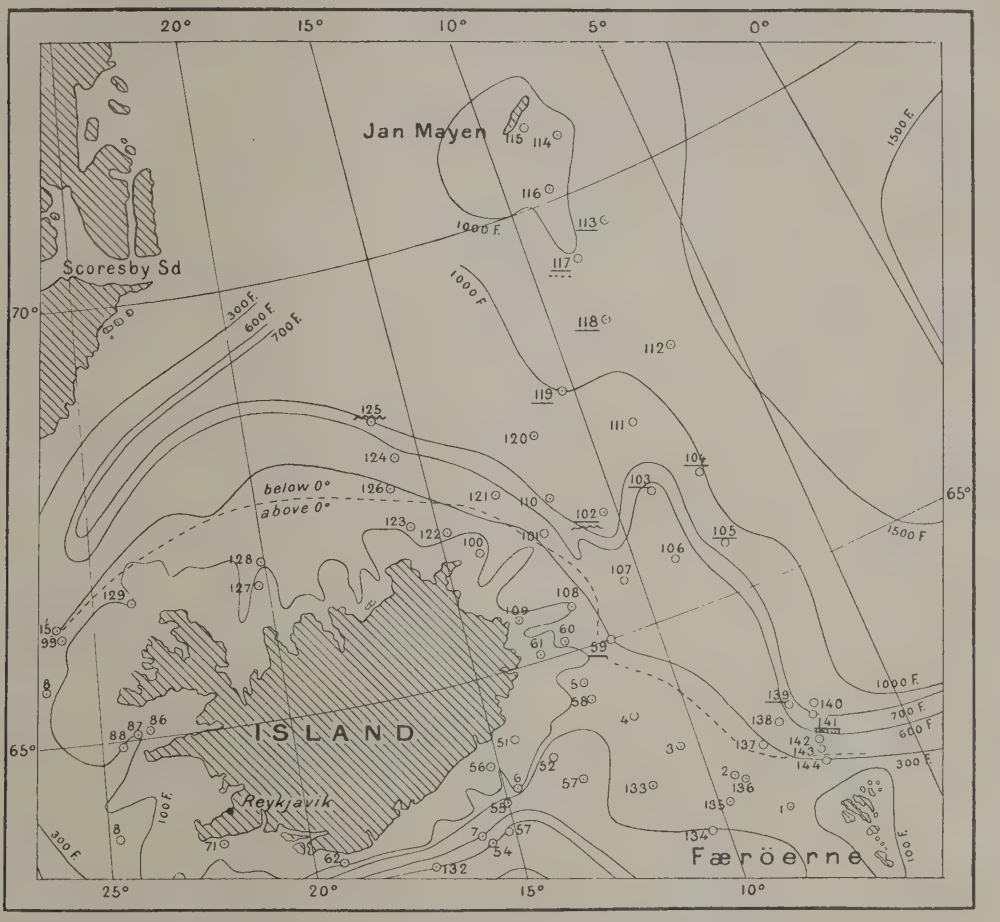

Fig. 4. A part of the area investigated by the Danish Ingolf Expedition.
The lines indicate the depths in Danish fathoms (F.). The dotted line indicates the border between bottom water of a temperature above and below 0° C. The figures with ⊙ are the numbers of the trawling stations. The stations where otoliths were found are marked below the figures ——, ~~~~, ... or ||||, which means otoliths of respectively *Gadus poutassou, Gadus saida, Gadus callarias* and *Gadus virens*(?).

masses of diatoms) which are found together with it on the ice-foot. They are all litoral forms, which are living among the ice-floes. His opinion is plainly enough that they are a part of the fauna and flora of the shore, which by the drifting ice has been carried out on the open sea, and I believe, he is

[1]) The Norwegian North Polar Expedition 1893—1896. Scientific results ed. by Fridtjof Nansen, IV, 1899. An account of the birds by R. Collett and F. Nansen, p. 47, remark. — In the same place is pointed out, that the Norwegian sealers "Is-Mort" (that means "small fish of the ice") is *Gadus saida*.

right in this assertion[1]). But in this case the fauna and flora will probably be destroyed earlier or later during the drifting of the ice, namely by degrees when the ice-floes, to whose edges they are bound, reach more southern latitudes and melt away[2]). Thus we have the very simple explanation, how otoliths of *Gadus saida* may be deposited on the bottom of the Polar Deep N. and N. E. of Iceland ("Ingolf" St. 125 and St. 102).

Regarding the other *Gadus*-species this explanation does not hold good, as they do not live at arctic ice-covered shores, so we must here look for other reasons.

The few otoliths of *Gadus callarias* and *G. virens*(?) do not present much difficulty, however, when seen in the light of the later years' investigations. By some very interesting fishing experiments, which JOHAN HJORT made in the summer of 1900, he succeeded in proving that some cod-species may occur in the upper layers in the open sea, where the distance to the bottom is great[3]). On St. 9, N. of the Færoe Isles, sounding 1962 m., was caught in drift-net, shot 20 m. from the surface, 1 cod (*G. callarias*) of a length of 90 cm.; on tin bait was taken in the same place 1 green cod (*G. virens*) at a depth of 30 meters, 1 cod (*G. callarias*) of 94 cm. at 40 meters' depth; and on 400 hooks which were placed 30 meters below the surface 1 green cod (*G. virens*) was caught of a length of 100 cm. together with two cod *(G. callarias)* of a length of 84 and 94 cm. On St. 10, N. of the Færoe-Iceland ridge, sounding 640 m., were caught on 400 hooks placed ca. 60 m. from the surface 11 green cod (*G. virens*) of a length from 93—105 cm., and 1 haddock (*G. aeglefinus*) of 75 cm. On St. 46, W. of the Lofoten, sounding more than 3000 m., 1 fullgrown green cod (*G. virens*) was taken on lines near the surface[4]). As now HJORT to these observations adds similar experiences, made by fishermen and whalemen (communicated l. c.), he draws the far reaching conclusion that the mentioned cod-species in great numbers migrate over the large depths, and the very latest investigations by JOHS. SCHMIDT have partly confirmed the correctness of this assertion. SCHMIDT reports namely, partly that Færoe fishermen and especially French fishermen, when they are lying on great depths, frequently catch cod on their lines when placing them in the upper layers, partly that a considerable number of large cod were caught from the "Thor" in 30—60 fms. below the surface off East Iceland, where the depth was ca. 350 fms. SCHMIDT observed moreover that the stomach of such cod entirely contained pelagic animals (Schizopods and Copepods[5]). These facts that both the cod and the green cod are able to leave the bottom and live a pelagic life over great depths, at any rate for a shorter

[1]) The Amphipods and Diatoms from the ice-foot have not yet been worked out, so from those we can at present find no information. — In "Diatomaceae from the ice-floes and plankton of the Arctic Ocean" (The Norwegian North Polar Expedition 1893—96, ed. by F. NANSEN, XI, 1900) H. GRAN has worked out the Diatomaceae samples, which were collected from the drift ice during NANSEN's North Polar expedition. In the canals between the ice-floes and on the "ice-foot" *Nitzschia* (*frigida*), *Fragilaria* and *Melosira* (*hyperborea*) play an important rôle: "They all have a rather wide distribution, but they only occur in cold seas and especially between ice-floes, or where the sea is covered with ice".

[2]) It is however most likely that *Gadus saida* sometimes with the ice is carried quite down to the Icelandic coasts and landed there in living state, for I can hardly believe the polar-cod to be stationary at Iceland, as the Zoological Museum of Copenhagen only possesses 2 specimens sent down from North Iceland (Øfjord) in 1862 and 1869. To feel sure I wrote to the Icelandic ichthyologist BJARNI SÆMUNDSSON in Reykjavik, and in a letter dated April 28th 1904 I obtained the following reply: "I never saw nor heard of *Gadus saida* in the North of Iceland, though I saw much fish caught there and tried to obtain information regarding it".

[3]) It must here be remembered that FRIDTJOF NANSEN as early as twenty years ago found almost quite fresh specimens of another large food-fish, viz the norway haddock (*Sebastes marinus*), in the stomach of the bladder-nose in the middle of the Arctic Ocean, between Jan Mayen and Spitzbergen, where the depth exceeds 1500 fms. On account of this he came to the conclusion that the norway haddock is not, as formerly supposed, entirely a bottom-fish which only occurs at the coasts, as the fishes caught by the seal must have lived far from the bottom, higher up in the water and at a distance from the surface corresponding to the depth, at which the norway haddock occurs at the coasts, thus about 60 fms. He believes that *Sebastes marinus* occurs "possibly in this way all over the Arctic Ocean" (F. NANSEN: De norske Fiske; Norsk Fiskeritidende, 5. Aargang, 1886, p. 73). That NANSEN had arrived at a correct conclusion of his observation was fully confirmed by HJORT's fishing-experiments in the year 1900.

[4]) "Michael Sars" første Togt i Nordhavet Aar 1900, under Ledelse af JOHAN HJORT. Aarsberetning vedkommende Norges Fiskerier for 1900, 4. Hefte, p. 264. (Bergen 1901.)

[5]) Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903 af JOHS. SCHMIDT, p. 70—71 and p. 127—128. (København 1904.)

time, are more than sufficient to account for the presence of the few otoliths of *G. callarias* and *G. virens*(?) at the bottom of the Polar Deep south of Jan Mayen and north of the Færoe Isles ("Ingolf" St. 117 and and St. 141). The otoliths may very well be supposed to originate from individuals which have perished on their way over the Polar Deep.

But what about the numerous otoliths of the Poutassou (*Gadus poutassou*) on the bottom of the Polar Deep between the Færoe Isles and Jan Mayen? To my mind different observations seem to indicate that this small cod partly lives a pelagic life over great depths. I shall first refer to the fact that several smaller specimens of *G. poutassou*[1]) were caught in "pelagic" trawl from the "Michael Sars" in the summer of 1900 on St. 9, north of the Færoe Isles, sounding 1962 m. (comp. HJORT l. c. p. 258 and 263). Mr. GEMZÖE has moreover given to the Zoological Museum of Copenhagen a *G. poutassou* of a length of 11·3 cm. which on September 9th of 1904 was thrown on the deck of the Danish man of war "Beskytteren", while it was about half-way between Iceland and the Færoe Isles (ca. 62°25½′ N. 8°37′ W.). Its stomach is full of Copepods. To this comes, what JOHS. SCHMIDT on my inquiry kindly has communicated, that during the "Thor"s cruise in 1903 pelagic fry of *G. poutassou* was caught south of Iceland far out on the open sea[2]), much further out than the fry of other cod-species. The fry of this *G. poutassou* was so small (6—16 mm.) that SCHMIDT thinks the fullgrown fishes must have spawned in the very regions, where the fry was taken over great depths (partly more than 1000 fms.). These observations indicate as before said, partly indirectly, partly directly, that *G. poutassou* really moves over great depths[3]). But in this case it would perhaps not be unreasonable to imagine that it, at any rate occasionally, also migrates out over that part of the Norwegian Sea, which is situated between the Færoe Isles and Jan Mayen (the "Michael Sars"s before mentioned St. 9, where *G. poutassou* was caught in 1900, was situated N. of the Færoe Isles over a depth of 1962 m.), as Atlantic water of a proportionally high temperature and salinity (the Gulf-Stream)[4]), as is a well-known fact, invades the Norwegian Sea over the ridge between the Færoe and Shetland Isles and sometimes in summer may approach this line, while it as a rule keeps to the eastern part of the Norwegian Sea[5]). The course of the current in the Norwegian Sea is hardly more constant than we may compare the upper layers of this sea with a vast battle-field, where atlantic and arctic water fight for the predominance and are objects of shiftings. Thus it is not unimaginable that shoals of the *G. poutassou*, which are moving in the surface, might follow the warm Atlantic current outside their proper home to the western part of the Norwegian Sea and here be cut off from the retreat by the cold arctic current. The fish then would perish; and when the demolishing power of the sea had destroyed the softer parts and the skeleton, an accumulation of the otoliths might take place on the sea-bottom.

From another sea-territory we possess really in modern time a striking proof, how a sudden

[1]) HJORT mentions them as "fry", but the stated length (14—15 cm.) informs us that they have been not quite young fishes.

[2]) St. 87: 61°40′ N. 13°33′ W.; St. 88: 61°30′ N. 13°33′ W.; St. 91: 61°30′ N. 17°08′ W.; St. 92: 61°31′ N. 19°05′ W.

[3]) Once *Gadus poutassou* has been observed to swim in the surface of a lesser depth, according to a statement by HOLT and CALDERWOOD: "On the 10th July, 1890, while the trawl of the S. S. "Fingal" was down at 175 fathoms, thirty-four miles off Achill Head, a large shoal of young Poutassou was observed at the surface. They were darting violently about, and a number were easily captured in a large tow-net. According to the mate, who was the first to observe them, they were being chased by a large squid, which, however, had disappeared by the time the attention of Mr. GREEN and Prof. HADDON had been called to them. The fish captured were carefully examined by one of us a few minutes afterwards, but they presented no sign, by distension of the airbladder or otherwise, of having been driven upwards from any considerable depth. It may therefore be supposed that, previous to their disturbance, the fish were swimming at or near the surface. The stomachs were full of small crustaceans, copepods, etc..... All the specimens taken were much alike in size, the total length ranging from 5½ to 6 inches". (Survey of Fishing-Grounds, West Coast of Ireland, 1890—91. Report on the Rarer Fishes. By E. W. L. HOLT and W. L. CALDERWOOD. The Scient. Trans. Royal Dublin Soc., Series II, vol. V, 1895, p. 430.)

[4]) *Gadus poutassou* is, according to our knowledge, no arctic fish. Its distribution extends from the Mediterranean up to Hammerfest, but north of Bergen it becomes already proportionately rare; towards the west it is caught (by the "Thor" 1903) S. W. of the Færoe Isles and S. of Iceland.

[5]) Comp. FRIDTJOF NANSEN: Some Oceanographical Results of the Expedition with the "Michael Sars" in the summer 1900; Nyt Mag. f. Naturvidensk. B. 39. H. 2. Chria. 1901.

alteration in the course of the current has caused the destruction of a fish-species in millions of specimens, a fact which I now shortly shall mention. In May of 1879 were caught several thousand lbs. of a fish, which neither fishermen nor scientific men knew. They were taken from a fishing-vessel which had set lines to catch cod on a depth of 80—120 fms. S. of Nantucket, an island at the Atlantic coast of the United States (off Rhode Island). The fish was called "tilefish" on account of its magnificent colour, and it was described by GOODE and BEAN under the name of *Lopholatilus chamaeleonticeps*. It belongs to the Trachinoids and is by JORDAN & EVERMANN referred to the family *Malacanthidae*[1]). As it was a good-sized fish, which on an average weighed more than 10 lbs. a piece, and as its meat tasted well, and the fish was easily saleable, the Fishery-Commission of the United States dispatched in 1880 and in 1881 the vessel "Fish Hawk" in order to discover the most favourable fishing-grounds. They succeeded in catching a quantity of tilefish at depths from 126—134 fms. and expected much profit from the new article. But in 1882 a catastrophe occurred. Different vessels, which in March and April arrived at New York, Boston and Philadelphia, reported that they on their voyage had passed millions of dead fishes drifting on the sea at the northern edge of the Gulf-Stream. According to careful investigations by Captain J. W. COLLINS an area of a length of 170 miles and a breath of 25 miles is supposed to have been covered with dead fishes, whose number at a low estimate amounted to 1·438·720·000 specimens. According to the description the bulk appear to have been tilefish. The fishes showed no trace of illness, parasites did not appear in numbers and volcanic eruptions or similar phenomenons, which might be supposed to have caused the destruction of the fishes, were not noticed. Prof. A. E. VERRILL was at the same time able to point out that great changes also had taken place in the lower fauna. The rich animal life of tropical and subtropical forms, which he had noticed on the tilefish-grounds in the years 1880 and 1881 had now highly decreased. Many species, especially crustacea, which formerly occurred in vast numbers, were now scarce or quite wanting. According to VERRILL's opinion we shall have to seek the cause of this sudden change of the fauna in hydrographical conditions. Off New England outside the 100 fathom-line the sea-bed slopes very rapidly downwards. The bottom along the upper part of this slope and the outermost portion of the adjacent plateau, in 65 to 150 fms., and sometimes 200 fms. or more, is bathed by the waters of the Gulf Stream. The bottom temperature is thus along this belt decidedly higher than along the shallower part of the plateau near the shore, in 25 to 60 fms., as this part is watered by the cold Labrador Stream. Further out at a more considerable depth, much colder water occurs on the bottom beneath the Gulf-Stream. Along the bottom the "warm belt" is consequently very narrow. As long as the Gulf-Stream constantly was flowing along this area at the bottom, a tropical and subtropical animal life might live in this narrow warm belt and exist as far up as to New England as a northern continuation of the West Indian fauna. In this animal life was included *Lopholatilus* which no doubt is a tropical fish. Its nearest relatives are, at any rate, known to live in the tropical or subtropical seas. But in the moment when the Gulf-Stream retired from the edge of the continental platform and the cold coast-stream invaded the "warm belt" its peculiar southern animal life was doomed to perish in consequense of the sudden fall in the temperature. According to VERRILL's opinion such an occurrence had taken place in 1882. During 1883—87 we obtained certainty that *Lopholatilus* had disappeared, as not a single specimen was caught during all these years in spite of numerous attempts made both with dredge and line. In 1889 a systematical investigation of the relations between the Labrador- and the Gulf-Stream was commenced off the southern New England. These investigations proved among others, that a belt of deep and warm water, of 50° F. and more, year by year approached the continental edge, touched it, and finally extended over the bottom, where *Lopholatilus* formerly occurred. Prof. VERRILL had predicted, when this happened, that the southern species, also the tilefish, would in the lapse of few years migrate towards the North and

[1]) JORDAN & EVERMANN: The Fishes of North and Middle America, Part III, 1898, p. 2278.

recover the possession of their old grounds. His prediction came true. After 10 years, namely in August 1892, the Fish Commission schooner "Grampus" caught one *Lopholatilus* on its lines; the fish was however still so scarce that the continued searching during two months only brought forth 8 specimens. In 1893 53 tilefish were caught and in 1898 they occurred abundantly everywhere on their old grounds, not only large fish, but also many very young ones, so that the species probably now is spawning on the ground [1]).

When regarding this event it is not absurd to suppose, that *Gadus poutassou* in those northern regions may have met with a similar fate once or several times. It may have followed the salt and warm Atlantic water out on the surface of the Norwegian Sea, where a change of the current may have prevented it from retiring back, when arctic water invaded the area, over which it would have to move in order to get away. Cut off from a retreat such erring shoals would perish on the surface of the Norwegian Sea, what would explain the phenomenon that otoliths of *Gadus poutassou* are deposited in vast numbers on the bottom of the Polar Deep between the Færoe Isles and Jan Mayen.

We might also presume another cause of the destruction of the *Gadus poutassou* shoals, viz. fish-eating whales, which are not wanting in that sea: *Balaenoptera musculus*, Comp., *B. rostrata*, Fabr., *Megaptera boops*, Fabr. and *Phocaena communis*, Cuv. to mention some of the more important. The objection that the otoliths would become decomposed by passing the whales' intestinal canal hardly holds good. I shall in this respect refer to an interresting note which lately was published by Thomas Scott: In the stomach of a porpoise (*Phocaena communis*) which had become entangled in salmon-net at Nigg Bay and was drowned, he found, besides partly digested remains of fishes, 280 otoliths, among which he was able to identify 240 with almost perfect certainty as belonging to the Whiting (*Gadus merlangus* L.). Many of the otoliths were found scattered among the partly digested fish-bodies, but by far the larger number were found neatly packed together in the narrow distal end of the stomach; these ear-stones were remarkably clean and perfect. Scott presents a photograph of the otoliths, by which we may convince ourselves about the thruth of his words [2]). From the accumulation of the otoliths at the pylorus and their state there, we may presumably be justified in concluding that they would have passed into the intestine without being decomposed, and would have been evacuated, if the porpoise had continued to live. Thus it appears that whales "isolate" the otoliths of the fish, which they swallow, and evacuate them in indecomposed state.

Before I finish the discussion I shall only emphasize that the practical-scientific investigations, which since the year 1900 also have made the Norwegian Sea a part of its working-field, have furnished us with the key to the right solving of the problem in question. On one hand it must be regarded as proved that *Gadus*-species do not live in the Polar Deep, since no cod were caught in the "Michael Sars" powerful otter-trawl; on the other hand it is made evident that cod-species horizontally may migrate from the shore-grounds and occur pelagically over great depths. From these facts we must draw the conclusion that the otoliths of *Gadus*-species, which are accumulated on the bottom of the Polar Deep, originate from specimens, which have moved in the upper layers. The polar-cod (*G. saida*) takes probably a peculiar position; it is by arctic expeditions noticed to follow the drifting ice over great depths, its migrations thus are probably passive.

[1]) H. C. Bumpus: The reappearance of the Tilefish; Bull. of the U. S. Fish Commission, XVIII, 1898 (Washington 1899), p. 321—33. This treatise contains reference to the more important literature regarding the "tilefish" and its history.

[2]) Scott: Note on the food observed in the stomach of a Common Porpoise. Twenty-first Annual Report of the Fishery Board for Scotland, Part III, 1903, p. 226.

That the otoliths of the fishes play a considerable rôle in marine deposits from the past geological periods (tertiary time) and occur by far more frequently than the skeletons is a well-known fact, especially since Prof. Ernst Koken in Tübingen with great energy has treated this branch of the paleontology and made the otoliths the object of a special study. But that otoliths in great quantities are deposited in the seas of the present time is, as far as I know, hitherto unknown.

In a later treatise I intend to go through the otoliths which I have picked out of bottom samples from the Atlantic Deep and from the coast of Iceland and the Færoe Isles.

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